PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 06 April 2001 (06.04.01)	
International application No. PCT/EP99/05202	**Applicant's or agent's file reference** JEB/4961WO
International filing date (day/month/year) 21 July 1999 (21.07.99)	**Priority date** (day/month/year)
Applicant SIGNAROLDI, Teresio et al	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   20 February 2001 (20.02.01)

   [ ] in a notice effecting later election filed with the International Bureau on:

   _____

2. The election [X] was

   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Claudio Borton
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
JEB/4961WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 99/ 05202	21/07/1999	
Applicant		
SAIPEM S.P.A. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 11

   [X] as suggested by the applicant.

   [ ] None of the figures.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/05202

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16L1/12 F16L1/19 B63B35/03

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16L B63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 21 18 360 A (BROWN & ROOT) 28 October 1971 (1971-10-28) page 6, line 4 - line 8 page 24, line 10 - line 23 figures 1,10,12A	1-4,6,7, 12, 15-17, 21-23
A		8-11,14, 18,19,24
X	US 4 865 359 A (ROBERTS RICHARD A) 12 September 1989 (1989-09-12) column 6, line 8 - line 38 figure 3	1,2, 15-17, 22,23
A		3-7,12, 18

-/—

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 March 2000	29/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Brosio, A

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 1 178 219 A (SOCIÈTÈ DES GRANDES TRAVAUX DE MARSEILLE) 21 January 1970 (1970-01-21) page 7, line 25 - line 34 figures 6,8	1-4,6,7, 12,14, 15, 17-19, 22,23
A	GB 1 107 541 A (SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ N.V.) 27 March 1968 (1968-03-27) figure 12 page 6, line 14 - line 22	5,13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 99/05202

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 2118360 A	28-10-1971	CA 929754 A	10-07-1973
		DK 137401 B	27-02-1978
		GB 1319199 A	06-06-1973
		NL 7104849 A	19-10-1971
		NO 135837 B	28-02-1977
		US 3680322 A	01-08-1972
US 4865359 A	12-09-1989	NONE	
GB 1178219 A	21-01-1970	BE 715438 A	16-10-1968
		DE 1750749 A	18-11-1971
		FR 1532570 A	20-11-1968
		LU 56097 A	09-09-1968
		NL 6807572 A	02-12-1968
		NO 131253 B	20-01-1975
		US 3524326 A	18-08-1970
GB 1107541 A		DE 1475819 A	30-10-1969
		NL 6503699 A	24-09-1965
		US 3331212 A	18-07-1967
		US RE28410 E	06-05-1975

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

Bardo, Julian E.
ABEL & IMRAY
20 Red Lion Street
London WC1R 4PQ
GRANDE BRETAGNE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

	Date of mailing *(day/month/year)* 10.10.2001
Applicant's or agent's file reference 4961 WO/JEB/VSB	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP99/05202	21/07/1999	21/07/1999

Applicant
SAIPEM S.P.A. et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Haase, G Tel.+49 89 2399-7532

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
4961 WO/JEB/VSB		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP99/05202	21/07/1999	21/07/1999
International Patent Classification (IPC) or national classification and IPC F16L1/12		
Applicant SAIPEM S.P.A. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
20/02/2001	10.10.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Vecchio, G Telephone No. +49 89 2399 7325

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP99/05202

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-23 as originally filed

Claims, No.:

1-24 as originally filed

Drawings, sheets:

1/13-13/13 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	8-11,16,18-20,24
	No:	Claims	1-7,12-15,17,21-23
Inventive step (IS)	Yes:	Claims	19,20,24
	No:	Claims	8-11,16,18
Industrial applicability (IA)	Yes:	Claims	1-24
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents:

   D1: DE 21 18 360 A
   D2: US-A-4 865 359
   D3: GB-A-1 178 219

2. Document D1 discloses (see particularly figures 1, 2, 10 and description thereof) a pipe-laying vessel including an upwardly extending tower assembly (32, 34) defining a path down which the pipe passes as a pipeline is being laid by the vessel, and a lower guide arrangement (30) for guiding the pipeline after it has passed down the tower, the lower guide arrangement including a plurality of sets of guide rollers (36) spaced apart along the path of the pipeline and defining the lateral limits of the path, the guide rollers being located such that they allow some bending of the pipeline as it passes through the lower guide arrangement.

   Therefore, the subject-matter of claim 1 is not new according to Article 33(2) PCT.

3. The applicant's attention is drawn also to documents D2 (see particularly figure 3, reference signs 110, 120, 124, 126) and D3 (see figures 6, 9, 10, reference signs 1, 28, 29, 32 and page 7, lines 1-41) which show the features defined in claim 1 and hence are considered as novelty destroying (Article 33(2) PCT) for the subject-matter of independent claim 1.

4. Similarly, both D1 and D2 disclose the steps claimed in independent claim 22, which defines the method of laying a pipeline from a vessel correspondent to the apparatus of claim 1.

   Hence, the subject-matter of independent method claim 22 is not new pursuant to Article 33(2) PCT.

5. Also the subject-matter of dependent claims 2-7, 12-15, 17, 21 and 23 is

anticipated by documents D1-D3; thus, it does not fulfil the requirements of Article 33(2) PCT:

- about claims 2 and 3, see D1 (fig.10) or D3 (figs. 9, 10);
- about claim 4, see D1 (fig.10);
- about claim 5, see D2 (fig.3);
- about claim 6, see D1 and D3;
- about claim 7, see D1 and D3 (fig.9);
- about claim 12, see D1 (fig.12A) and D3;
- about claim 13, see D2;
- about claim 14, see D1-D3;
- about claim 15, see D1 (figs.1 and 12A);
- about claim 17, see D1;
- about claim 21, see D1-D3;
- about claim 23, see D1 and D2.

6. Depending claims 8-11, 16 and 18 relate to minor constructional features which, insofar as not directly disclosed in the documents cited in the search report, represent only obvious modifications thereof. Such features will be selected by a skilled person in accordance with circumstances because the advantages thereby achieved can be readily contemplated in advance. The combination of such features with any of claim to which they refer does not involve an inventive step in the sense of Article 33(3) PCT.

7. The subject-matter of claim 19 is not disclosed in, nor rendered obvious by any prior art document. The "means for monitoring the forces applied to the pipeline by the rollers of the lower guide arrangement" allows a more efficient laying of the pipeline than that as known from the prior art, where means for merely prevent over-stressing is the only described means.

   Therefore, the subject-matter of claim 19, and thus that of its directly depending claim 20 and of its corresponding method claim 24, is inventive as provided by Article 33(3) PCT.

8. The industrial applicability of the claimed invention is clearly given in the description pursuant to Article 33(4) PCT.

Re Item VII

Certain defects in the international application

1. Independent claims 1 and 22 are not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the chosen closest prior art being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

2. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in at least one of the documents D1-D3 is not mentioned in the description, nor is this document, which will be chosen as the closest prior art, identified therein.

3. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

4. It is here observed that the definition "below sea level" in claims 15 and 16 is not limiting the scope of the claims because it is not related to features which are part of the subject-matter of the claim, i.e. the vessel.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 February 2001 (01.02.2001)

PCT

(10) International Publication Number
WO 01/07812 A1

(51) International Patent Classification[7]: F16L 1/12, 1/19, B63B 35/03

(21) International Application Number: PCT/EP99/05202

(22) International Filing Date: 21 July 1999 (21.07.1999)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: SAIPEM S.P.A. [IT/IT]; Via Martiri di Cefalonia, 67, I-20097 San Donato Milanese (IT).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: SIGNAROLDI, Teresio [IT/IT]; Via Turati, 7, I-26858 Sordio (IT). BIANCHI, Stefano [IT/IT]; Via Filippo Corridoni, 15, I-20063 Cernusco sul Naviglio (IT).

(74) Agents: BARDO, Julian, Eason et al.; Abel & Imray, 20 Red Lion Street, London WC1R 4PQ (GB).

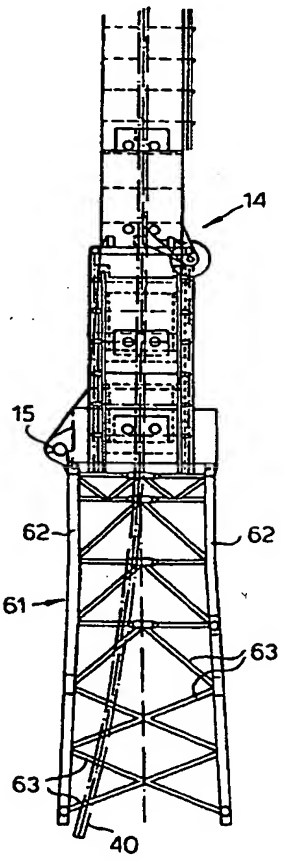
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: IMPROVEMENTS IN AND RELATING TO UNDERWATER PIPE-LAYING



(57) Abstract: A pipe-laying vessel includes an upwardly extending tower (14) assembly defining a path down which the pipe passes as a pipeline (40) is being laid by the vessel, and a lower guide arrangement for guiding the pipeline after it has passed down the tower, the lower guide arrangement (61) including a plurality of sets of guide rollers spaced apart along the path of the pipeline and defining the lateral limits of the path, the guide rollers being located such that they allow some bending of the pipeline as it passes through the lower guide arrangement.

WO 01/07812 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Improvements in and relating to Underwater Pipe-Laying

The invention relates to a pipe-laying vessel and to a method of laying a pipeline.

The technique mainly used up to now to lay pipelines in the sea is that called "S laying". This technique can be described briefly as follows. The pipe joints, generally 12 metres long, are transported from a port to a lay-barge by means of supply barges or supply vessels, and are loaded onto the deck of the lay-barge. Those pipe joints are added one after the other along a construction ramp, which is usually horizontal or in some cases has a small inclination of 5 or 10 degrees (this ramp being called the "firing line"). On the firing line the operations necessary to complete the connection of the pipe joints are performed in several working stations in order to build a continuous pipeline. When a new joint is added, the barge moves forward and the pipeline, supported at the stern of the lay-barge by an inclined ramp (or floating stinger) curves over the stern of the barge down toward the seabed. The profile of the pipeline, from the lay-vessel to the seabed, is in the form of a long "S" (from which comes the term "S lay"). The upper part of the profile is called the "over-bend", and the lower part is called the "sag-bend". In order to reduce the stresses on the suspended part of the sealine on its way from the lay-vessel to the sea bottom, a constant tension is maintained on the pipeline by means of machines called tensioners. There is a maximum to the depth of water in which that method can be used. As the water depth increases, the tensioner pull necessary to maintain the pipe stress within acceptable values increases dramatically, and the horizontal bollard pull on the lay vessel increases

correspondingly. A method to reduce the above-mentioned pulls consists of increasing the angle of descent of the sealine in to the sea. If the angle is close to vertical (called "J lay") the necessary tension on the pipe is very close to the weight of a length of the sealine string equal to the water depth, and the horizontal component is close to zero. This method has the contrary limitation that there is a minimum to the depth of water in which it can be used, because the pipeline must have room to curve through about 90° to lie on the seabed, and if the pipeline is too tightly curved it will be over-stressed.

The problem of over-stressing of the pipeline, especially when it is relatively inflexible, when using a J laying technique has restricted the use that can be made of J laying and more particularly limited the conditions under which J laying has proved a suitable technique.

It is an object of the invention to provide a pipe-laying vessel and a method of laying a pipeline in which the problem of over-stressing the pipeline when J laying is reduced, thereby permitting the effective use of J laying in a wider range of conditions.

According to the invention there is provided a pipe-laying vessel including an upwardly extending tower assembly defining a path down which the pipe passes as a pipeline is being laid by the vessel, and a lower guide arrangement for guiding the pipeline after it has passed down the tower, the lower guide arrangement including a plurality of sets of guide rollers spaced apart along the path of the pipeline and defining the lateral limits of the path, the guide rollers being located such that they allow some bending of the pipeline as it passes through the lower guide arrangement.

By allowing bending of the pipeline as it leaves the vessel and controlling the bending of the pipeline the likelihood of over-stressing the pipeline as it leaves the vessel is reduced. It becomes possible to arrange for the horizontal forces applied to the pipeline by the vessel during laying to be spread between the various sets of guide rollers, so that the stresses introduced at any one set of guide rollers are reduced.

It will usually be preferable for the guide rollers to be of cylindrical shape, but other shapes can be adopted if desired and it is even possible for revolving tracks to be provided around some or all of the rollers, should that be desired for some reason.

Preferably the guide rollers of at least one set of rollers include rollers whose axes of rotation, in a plane perpendicular to the tower, are inclined to one another. In that case the guide rollers surround, at least to some extent, the pipeline and, thereby, allow for some variation between the alignment of the vessel and tower assembly on the one hand and the vertical plane containing the undersea pipeline being laid on the other hand. Preferably the guide rollers of at least one set of rollers extend at least one quarter of a revolution around the path of the pipeline; that allows for a variation of about 90 degrees between the alignment of the vessel/tower assembly on the one hand and the undersea pipeline on the other hand. More preferably the guide rollers of at least one set of rollers extend substantially all around the path of the pipeline; the guide arrangement is then operative for all orientations of the vessel relative to the undersea pipeline.

The lower guide arrangement is preferably of substantially trumpet shape flaring outwardly in the

direction of travel of the pipeline during laying, the angle of flare increasing in the direction of travel of the pipeline during laying. In that case, whichever region of the guide arrangement is acting to guide the pipeline as it is being laid, has the effect of introducing a controlled bend into the pipeline and forces applied to the pipeling are spread between rollers of various sets.

Whilst it is within the scope of the invention for the guide rollers to fulfill some tensioning purpose, it is preferred that the guide rollers are freely rotatable so that substantially the only force applied to the pipeline by the guide rollers is a lateral force.

At least some of the rollers are preferably mounted for rotation on bearings that are directly or indirectly resiliently displaceable. It is advantageous to provide the resilience by allowing the axis of rotation of the roller to change resiliently rather than by, for example, providing a resilient roller structure so that the effective direction of the roller changes. It is possible for each roller to be mounted individually for resilient displacement but preferably a whole set of rollers is mounted on a structure that is resiliently displaceable.

The invention is of particular relevance to the laying of a relatively rigid pipeline rather than, for example, a pipeline that is so flexible it can be curved into reels for storage. Preferably the resistance of the bearings to resilient displacement is more than 100kN/m, and more preferably more than 500kN/m. In an embodiment of the invention described below, the resistance to displacement is of the order of 5000kN/m in the case of certain higher sets of rollers and of the order of 1000kN/m in the case of certain lower sets of rollers.

The bearings are preferably resiliently displaceable by a distance of more than 50 mm and preferably at least some of the bearings are resiliently displaceable by a distance of more than 100 mm. In an embodiment of the invention described below, the higher sets of rollers with a resistance to displacement of 5000kN/m are able to be displaced 100 mm and the lower sets of rollers with a resistance to displacement of 1000kN/m are able to be displaced 300 mm.

As will be appreciated, the amount of bending introduced into the pipeline during its passage through the lower guide arrangement may be small. One purpose of introducing the bend is to enable the horizontal forces between the guide rollers and the pipeline to be distributed evenly between the sets of rollers. In an embodiment of the invention described below, the amount of bending of the pipeline is of the order of 0.34 m per 10 m length of pipeline; in that embodiment the total force applied by the lower guide arrangement under normal conditions is about 1000kN.

The inclination of the tower assembly is preferably adjustable so that the angle of laying the pipeline can be adjusted, for example according to the depth of laying. The lower guide arrangement is preferably secured to the tower assembly; it is then automatically adjusted with the tower assembly. The inclination of the tower assembly may be fixed, for example, in a vertical position. The inclination of the tower assembly during use is preferably in the range of 45° to 90° to the horizontal.

Preferably three or more sets of guide rollers, and more preferably five or more sets of guide rollers, are positioned along the path of the pipeline below sea level. Some sets of guide rollers are preferably also positioned

along the path of the pipeline above sea level; bending of the pipeline is then able to begin above sea level and, in the case where the tower is pivotable, even above the axis of pivoting of the tower. Preferably the sets of rollers are spaced apart substantially evenly along the path of the pipeline. The spacing along the path of the pipeline between adjacent sets of guide rollers is preferably in the range of 2 m to 15 m and more preferably in the range of 3 m to 10 m. In an embodiment of the invention described below, the spacing is about 5 m.

Preferably the vessel includes means for monitoring the forces applied to the pipeline by the rollers of the lower guide arrangement. Preferably a plurality of force monitoring means are associated with respective sets of guide rollers for monitoring the forces applied to the pipeline by the respective sets of guide rollers. The monitoring means may comprise a plurality of load cells.

The vessel may include means for raising lengths of pipe from a deck of the vessel to a position aligned with the tower assembly and for joining such lengths of pipe to the pipeline being laid.

According to the invention there is also provided a method of laying a pipeline from a vessel, comprising lowering the pipeline down an upwardly extending tower assembly of the vessel and then through a lower guide arrangement, the lower guide arrangement including a plurality of sets of guide rollers spaced apart along the path of the pipeline and defining the lateral limits of the pipeline, the pipeline undergoing some bending as it passes through the lower guide arrangement.

The vessel employed in the method of the invention may be in any of the forms defined above.

Preferably, forces exerted on the pipeline by one or more of the guide rollers are monitored and the operation of the vessel adjusted in dependence upon the monitoring.

Certain forms of pipe-laying vessel will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a sectional side elevation view of a pipe-laying vessel;

Fig. 2 is a front elevation view of the vessel;

Fig. 3 is a top plan view of the vessel, partly in section;

Fig. 4 is a section through a pipe preparation area of the vessel, to a larger scale than Fig. 1;

Fig. 5 is a side elevation view of the tower, to a larger scale than Fig. 1;

Fig. 6 is a cross-section through the tower, along the line A - A in Fig. 5;

Fig. 7 is a cross-section through the tower, along the line B - B in Fig. 5;

Fig. 8 is a longitudinal section through part of a lower ramp portion of the tower;

Fig. 9 is a cross-section along the line C-C in Fig. 8;

Fig. 10 is a side elevation view of part of the vessel;

Fig. 11 is a side elevation view of the lower portion of a tower similar to that shown in Figs. 5 to 10 but including a modified form of lower guide arrangement for the pipeline;

Fig. 12 is an end elevation view of the lower portion of the tower shown in Fig. 11;

Fig. 13 is a diagrammatic side view of the lower portion of the tower shown in Fig. 11 indicating the spatial arrangement of guide rollers in the modified lower guide arrangement;

Fig. 14 is a sectional plan view through a lower region of the modified lower guide arrangement;

Fig. 15 is a sectional plan view to a larger scale than Fig. 14 through part of the same lower region of the modified lower guide arrangement;

Fig. 16A is a sectional view along the line D-D in Fig. 15 of a guiding part of the modified lower guide arrangement with the guiding part in an unstressed condition;

Fig. 16B is a sectional view along the line D-D in Fig. 15 of a guiding part of the modified lower guide arrangement with the guiding part in a stressed condition;

Fig. 17A is a sectional plan view through an uppermost region of the modified lower guide arrangement;

Fig. 17B is a sectional plan view through an upper region of the modified lower guide arrangement; and

Fig. 17C is a plan view to a larger scale of a roller arrangement of the kind shown in Figs. 17A and 17B.

Referring to the drawings, and initially to Figs. 1 to 3, one pipe-laying vessel, indicated generally by the reference numeral 1, is a semi-submersible vessel arranged to be propelled and manoeuvred by propeller thrusters 2. The vessel is equipped with two large rotatable cranes 3, mounted one on each side of the bow, which may be of conventional design and, in the interests of simplicity, will not be further described or shown in detail.

The cranes 3 carry on board containers 4 of pipes, which are brought by cargo barges or the like (not shown) and stow them on the deck on both sides of the ship bulkheads.

Pipes 5 are then delivered by crawler cranes 6 and conveyors (not shown) to a double-quadruple joint area,

which is accommodated within a module 7 fixed to the deck of the vessel 1 (see Figs. 3 and 4). The quadruple joint module 7 is placed on the starboard side of the firing line.

The crawler cranes 6 first move the pipes 5 from the stackers, which may be storage stacks on the vessel or may be containers in which the pipes are loaded onto the vessel, to a bevelling station module 8 that is positioned on the port side of the ship, just aside the centre line. After the ends of the pipes 5 have been bevelled, transverse conveyors transfer the pipes to a double joint area 9 of the quadruple joint module 7, where the single joints are welded together. The transverse conveyors may consist of cradles movable along rails running across the vessel. The pipes 5 may be supported on the cradles by rollers that allow lengthwise movement of the pipes and can be adjusted to support pipes of different diameters.

The quadruple joint module 7 has two different levels. In the double joint area 9, at the lower level, four pipes 5 at a time, just arrived from the bevelling station, are conveyed to the appropriate positions in the module and then welded together in pairs into double joint strings 10. Welding is carried out by means of four welding stations, and the welds are X-ray checked at a fifth working station. If the weld has been performed correctly, the double joint strings 10 are lifted up to the second level, to the quadruple joint area 11. Otherwise the joint is moved outside the joint module structure 7 in order to be repaired or, if it cannot be repaired, to be cut. At the quadruple joint area 11, two double joint strings 10 are welded together (by means of four welding stations) and then checked in a fifth working station (NDT station) to form a quadruple joint string 12.

If the string 12 is satisfactory, it is transferred horizontally to the centre line of the vessel, where there is a conveyor arranged to move it towards the bow. If the NDT detects a bad weld, the pipe string is shifted aside to the port side of the vessel 1 to be repaired or cut. If a cut is necessary, the quadruple joint 12 is split into four single joints 5 and then transferred back to the bevelling station 8, where it is bevelled again before being returned to the welding process.

At the bow of the vessel 1, on the centre line, between the two cranes 3, is a lay tower indicated generally by the reference number 14. The tower 14 is designed to allow simple installation and removal. The tower 14 is coupled to the hull of the vessel by means of two hinges 15 capable of varying the operational lay slope, which is defined by the longitudinal axis of the tower, from 90° to 120° (from the vertical position to 30° outboard). That movement is necessary to lay various pipe sizes in different sea depths (from shallow to deep water). The angle of the tower 14 is determined by a pivoting jacking system, described below.

The tower 14 is essentially constructed in three sections as can be seen in Fig. 5:

The lowest section or basket 16 is designed to support the maximum pulling force on the pipe, received by one or more friction clamps 18. It accommodates the clamps 18 and has at its lower end a lower ramp 17 carrying one or more terminal rollers 41 that guide the pipeline 40 as it leaves the vessel. It is preferably designed so as to be installed and removed by the cranes 3, or by an auxiliary crane vessel, and stored on the deck or on a barge. The friction clamps 18 comprise at least a fixed clamp arranged to hold the sealine 40

securely during interruptions in laying. Preferably, there is also a clamp movable on hydraulic jacks, which can be used when laying objects attached to the pipe that are too large or too irregular to be gripped properly by tensioners.

The middle section 19 accommodates three tensioners 20 which, in operation, lower the pipeline into the water while maintaining it at a desired tension, and pipe support rollers to guide the pipe when the tower 14 is not vertical. The tensioners are crawler-track tensioners of a sort that has been well known for some years in S laying, and the pipe support rollers are also of a type known per se. They are not described in more detail. The middle section 19 also accommodates fold-away sheaves (not shown) for an abandonment and recovery system, when those sheaves are in their idle condition. An NDT and field joint station 21, with floating floor, is located at the lower end of the middle section. A welding station 23, with floating floor, is located at the upper end of the middle section. The distance between the welding stations 21 and 23 corresponds approximately to the length of a quadruple joint string 12 so that the top of a string can be at the station 23 while the bottom of the same string is at the station 21.

The abandonment and recovery (A/R) system comprises a double capstan winch (electrically driven) with its associated reel winder and with a steel wire rope. The wire rope will be driven to the fold-away sheave (placed on the middle part of the tower) and then connected to the pulling head. The A/R system is accommodated on the main deck in a central position on the centre line of the vessel 1, just beside the quadruple joint module.

The upper section 22 of the tower 14 is a comparatively lightly built structure, because it never needs to support the tension on the pipeline. It accommodates a coupling device, and a line-up station 24 (Fig. 2). The upper section 22 is of open construction, in order to allow simple transferring of the string 12 from a pipe loader, described below, to the line-up station 24. The upper section 22 can be installed onto and removed from the middle section 19 during on-board installation activity.

The jacking system that controls the tilting movement of the tower 14 uses booms 25 that are connected to the upper portion of the middle section 19 of the tower, on its sternward or inboard face, and to jacking devices 26 on a support base frame 28 positioned on the deck just astern of the cranes 3. The jacking system comprises hydraulic cylinders, the pistons of which each carry a set of four hydraulically-actuated locking pins that engage in a row of apertures in the booms 25. When the tower is not being jacked, it is held by similar locking pins that are mounted in fixed positions on the base frame 28. If the tower is to be moved by more than the stroke of the hydraulic cylinders, it is held by the locking pins while the cylinders return for another stroke.

The pipe string 12 that is waiting horizontally at the quadruple joint area 11 is transferred by longitudinal conveyors 29A towards a pipe loader 29 at the base of the tower 14. The longitudinal conveyors may consist of rollers 29A mounted with their axes oblique to the horizontal, so that they define a V-shaped envelope, within which the pipe moves. They are movable towards and away from the centre line, so that pipes of different

diameters can be conveyed at a desired height above the deck.

The pipe loader 29 consists mainly of a truss 30 that transfers the pipe 12 from the quadruple joint area 11 to the middle section 19 of the tower 14 by means of its own rotation around a hinge 31. Because it rotates, the loader can easily accommodate the different positions that the pipe must reach when rotated to the several operational laying angles (from 90° up to 120°). The loader truss 30 is designed to be as light as possible in order to reduce the inertia of the system. As may be seen from Fig. 3, the loader truss is on the starboard side of the firing line, and it accommodates clamping units 32 (Fig. 5) that firmly grip the pipe string 12 and hold it alongside the truss 30 during the rotation. The pipe string 12 is supplied horizontally by the roller conveyors 29A from the quadruple joint area 11 to the loader area, and is then, if necessary, immediately raised by pipe lifters (not shown in detail) to a position where it can be engaged by the clamping units 32 on the pipe loader 29. At the proximal end of the loader 29, a mechanical safety stopper 33 is installed to prevent the pipe from falling if there is a hydraulic failure of the clamps 32. In normal use, the pipe does not rest on the stopper 33, in order to avoid the risk of damage to the machined bevel at the end of the pipe.

The rotation of the pipe loader 29 is effected by means of two winches (not shown), both of them mounted in the A-frame 28. A hoisting winch, with a rope passing over a sheave on the tower, raises and lowers the pipe loader 29, while a back tension winch applies a constant tension in the opposite direction, in order to prevent uncontrolled movement of the pipe loader when it rotates

beyond the vertical position or as a result of the movement of the vessel. The winch speed is defined in order to perform the loading activity within the cycle time of the laying operation.

The function of the loader 29 is only to grab the pipe 12 (by means of the clamps 32) and rotate it to the same angle of tilt as the tower 14. As soon as the pipe 12 is lying along the tower 14, the loader 29 stops its movement and waits (holding the pipe) for the lowering of an elevator 34.

The elevator 34 takes the pipe string 12 from the loader 29 and transfers it to the level of the line-up station 24. The elevator 34 consists mainly of a trolley running in two railway tracks 35, positioned on the middle part 19 and the upper part 22 of the tower, on the port side of the centre line of the loader 29. The trolley carries openable clamps 37. As may be best seen from Fig. 6, when the clamps 37 are fully open they are withdrawn to the port side of the firing line, so that the loader 29 can raise the pipe string 12 alongside the elevator 34. When small pipes are being handled, guiding rollers may also be fitted. At the lower end of the elevator 34 is installed a safety stop to support the pipe string if there is any failure of the hydraulic clamps 37. When the loader 29 arrives at the tower 14 and the elevator 34 is in its lower position, the clamps 37 grab the pipe 12, and the clamps 32 release it. The elevator 34 then lifts the pipe to the upper position. Then, the pipe 12 is transferred to transfer clamps 38.

Three vertically spaced transfer clamps 38 are provided, to transfer the pipe string 12 from the elevator 34 to the line-up machine 24: Fig. 6 shows one of the transfer clamps in three different positions; the clamps

are arranged as independent units, each comprising a rotatable and extensible arm controlled by transducers, on which is installed a fully opening clamp. When the clamps are in the external position the elevator transfers the pipe to them, while when they are in the inner position the line-up machines 24 move transversely and take the pipe from them. If a pipe string 12 is delivered by the elevator 34 before the line-up machines 24 are free to receive it, the transfer clamps 38 can hold the pipe string in a standby position, as shown in Fig. 6. In addition, an umbilical may be inserted into the pipe string 12, and/or the lower end may be pre-heated for welding, while the pipe string is held in the standby position.

The line-up machines 24 are necessary for the correct alignment between the pipe string 12 and the sealine 40. They are capable of moving the pipe in all three dimensions. They consist of a mixture of roller clamps, which fix the horizontal position of the pipe string 12 but allow it to rotate, and at least one rotatable friction clamp by means of which the orientation of the pipe about its own axis can be adjusted. Each machine is structurally independent from the others, but they must be controlled by means of transducers in order to ensure the correct alignment of the machines during the alignment of the pipe. Between the line-up machines 34, guiding rollers are installed in order to ensure that the pipe 12 is adequately supported during laying, when the line-up clamps are open, even with the tower 14 in a tilted position.

Referring now to Figs. 8, 9, and 10, the lower ramp 17 carries the terminal rollers 41 in sets of 3 on bogies 42. During pipe-laying, each bogie 42 is urged into

engagement with the sealine 40 by a hydraulic cylinder 44, pressurised by an accumulator (not shown), while the load on the bogie 42 is monitored by a load cell 46. The movement of each bogie is controlled by a parallel linkage 48, while the fully retracted position can be set by means of screw-jacks 50. The terminal rollers 41 thus make it possible both to monitor and to control the alignment of the sea line 40 as it leaves the vessel. If greater control is required, several sets of bogies 42 may be mounted, one above another, as shown in Fig. 10, enabling a controlled deflection of the sealine, so that it can be laid at a slight angle to the axis of the tower 14, thus increasing the versatility of the vessel.

Below the terminal rollers 41 there are provided wire-guiding rollers 52. The rollers 52 are mounted on pivot arms 54, and are moved in and out by hydraulic cylinders 56. They are kept fully retracted during pipe-laying, but are advanced to guide the wire rope during the abandonment and recovery procedures.

A remotely operated vehicle 58 is carried on the vessel 1, for monitoring the touch-down of the sealine 40 on the seabed. Because the point of touch-down is directly below, or close to directly below, the stern of the vessel, the ROV may be operated from the stern deck of the vessel 1 without needing an inconveniently long tether. Instead, or in addition, the touch-down may be monitored directly by active or passive sensors 60 mounted on the rear of the vessel.

In operation, the pipe 12 is aligned by the line-up machines 24 and held by them while its lower end is welded to the upper end of the sealine 40 in the welding station 23. Then, the line-up machines are released, the vessel is moved forwards, the sealine is fed out by the

tensioners 20 by the length of a quadruple joint 12. Then, the join that has just been welded is tested in the NDT station 21, while a new joint 12, which has in the meantime been delivered by the loader 29 and the elevator 34, is fed by the transfer clamps to the line-up machines 24.

The tower 14 is constructed in three sections and is attached to the vessel, and the quadruple joint module 7 is constructed as one or more largely self-contained modules attached to the deck, in such a way that the entire pipe-laying equipment can be assembled or disassembled easily and quickly, allowing conversion of the vessel as a whole from use as a pipe-laying vessel to use as an ordinary semi-submersible crane vessel.

As an example, a vessel such as that shown in the drawings may have the following dimensions:

Length of vessel	200 metres
Height of tower	135 m
Pipe Diameter Range (O.D.)	from 4" to 32"
Max. diameter of objects to be laid with tensioners open	2.5 m
Lay depth range for 4" pipe	50 m to 3000 m
Lay depth range for 32" pipe	200 m to 2000 m
Maximum lay holding force (tensioners)	525 metric ton
Maximum lay holding force (movable clamp)	2000 metric ton
Lay tower angle	90° - 120°
Intermediate pull A/R winch (double capstan)	up to 550 metric ton (max.)
High pull A/R winch (linear winch)	2000 metric ton (max.)
Length of joint carry on board	12.2 m

Pipe string length (4 x 10 to 15m)	48.8 m
Lay phase time	2 min.
Maximum operational wave height (significant)	4 m

Figs. 11 to 17C show a modified form of lower guide arrangement 61 which can be used in place of the lower ramp 17 and results in a vessel embodying the invention. In Figs. 11 to 17C parts corresponding to parts shown in other drawings are designated by the same reference numerals. As shown in Figs. 11 and 12, the arrangement 61 generally comprises a tubular frame including four longitudinal members 62 and cross-bracing members 63 joined together to form a substantially rigid structure that is fixed to the bottom of the tower 14 by four legs (one at the top end of each of the members 62). The lugs are secured to the tower by respective pin connections.

Referring now also to Figs. 13 to 17C, the structure formed by the members 62 and 63 serves to support various assemblies at different levels, including fixed and mobile clamps 18A and 18B respectively (Fig. 13), three sets of adjustable rollers 64A, 64B and 64C and six sets of guide rollers 65A to 65F, each set comprising a ring of rollers as will be described more fully below.

The adjustable rollers 64A, 64B and 64C serve a purpose similar to that of the rollers 52 described with reference to Figs. 8, 9 and 10. The rollers 64A, 64B, 64C are mounted for radial movement and moved by respective hydraulic piston and cylinder arrangements. In the particular example of the invention described the sets of rollers 64A and 64B are each arranged as shown in plan view in Fig. 17A and comprise 4 rollers 66 equiangularly spaced around the pipeline path and the rollers of the set of rollers 64C are each arranged as shown in plan view in

Fig. 17B and comprise eight equiangularly spaced rollers 67. One purpose of the rollers 64A, 64B, 64C is to keep the pipeline (sealine) 40 within a central circular region of an adjustable radius so that the clamps 18A and 18B, which are operated only in special situations such as an emergency, are assured of gripping the pipeline. A further purpose of the rollers, however, and especially the rollers 64B and 64C is to allow some initial, controlled, bending of the pipeline even at their relatively high levels above sea level. Television cameras 69 (Fig. 13) and load sensors associated with the rotational mountings of the rollers can monitor the passage of the pipeline through the rollers and the extensions of the hydraulic piston and cylinder arrangements and the hydraulic pressures therein can also be monitored and adjusted.

In Fig. 17C one of the hydraulic piston and cylinder arrangements is shown by way of example. It will be seen that the roller 66 or 67 is rotatably mounted on a support 70 and a load pin 71 provides a measurement of the force exerted by the pipeline 40 on the roller 66, 67. The support is connected to the piston of one of the piston and cylinder arrangements 68 which includes a pressure transducer 72 for monitoring pressure in the cylinder and a position transducer 73 for monitoring the position of the piston relative to the cylinder.

Signals from the television cameras 69 and the transducers 72, 73 and load pins 71 are all passed back through a multicore cable 79 having junction boxes 80 to a control station 81 which may be provided in a tower control room. Control signals for the operation of the piston and cylinder arrangements 68 are passed down from

the control station 81 to a hydraulic supply and control valve station 82.

The arrangement of the six sets of guide rollers 65A to 65F will now be described in more detail with reference to Figs. 13, 14, 15, 16A and 16B. For convenience the arrangement of the set of rollers 65D will first be described, that being the set of rollers shown in Fig. 14. A steel ring 75 provides the main fixed structural support for the set of rollers and is of a diameter suited to the particular set of rollers 65D so as to extend circumferentially around them. The ring 75 is fixed to the four longitudinal members 62 of the lower guide arrangement via struts 76. Immediately inside the ring 75 is another ring-shaped member 77 on which the rollers 78 are rotatably mounted. The ring-shaped member 77 is connected to the ring 75 at four equiangularly spaced positions around the roller structure via resilient mountings 83 shown in Figs. 16A and 16B.

Referring in particular to Figs. 15, 16A and 16B, each of the rollers 78 is rotatably mounted at each end on bracket arms 85 which are fixed to the ring-shaped member 77 and project radially inwardly therefrom. The ring 75 has supports 86 welded to it at the four locations of the resilient mountings 83 and each support 86 has an upper arm 87 and a lower arm 88 which projects radially inwardly over the ring-shaped member 77. The arms 87, 88 are each joined to the member 77 by a respective block 89 of elastomeric material. Fig. 16A shows the blocks 89 in their unstressed state, whilst Fig. 16B shows the blocks 89 in a stressed state following radially outward movement of a roller 78 (and therefore corresponding movement of the member 77) as a result of the force exerted by the pipeline 40. It can be seen from Fig. 16B

that the blocks 89 undergo shear strain to accommodate the movement.

Load cells (not shown) are associated with each of the sets of guide rollers 65A to 65F and signals from the load cells are passed back to the control station 81 via the junction boxes 80 and the cable 79. Signals from the load cells can be used by a controller to alter the pipe laying operation or adjust the direction or speed of travel of the vessel or the like.

Operation of the guide rollers during laying of a pipeline will now be described. In order to simplify the description, it will be assumed that the tower is oriented vertically, but it should be understood that the guide arrangement operates in substantially the same way when the tower is inclined. Also, for ease of description, it will in the first place be assumed that the vessel is travelling directly above the path on which the pipeline is being laid and is aligned with the path.

In order that the curvature of the pipeline in the region of the seabed should not be excessive, it is important that during laying of the pipeline a horizontal force is applied to the pipeline by the vessel in the direction in which the pipe is being laid and that a tensioning force is also applied. At the same time the force must be applied in a way that does not cause undue local stress in the pipeline.

Consequently, it is desirable that each of the sets of rollers 65A to 65F apply a horizontal force to the pipeline and, desirably, each set of rollers applies substantially the same force. That is achieved in the embodiment of the invention by arranging the sets of rollers so that they are positioned along a curved path allowing a degree of controlled bending of the pipeline as

it passes through the sets of rollers. The resilient mounting of the rollers further assists in promoting an even application of loads amongst the various sets of rollers.

An especially valuable feature of the design of the guide arrangement is that each set of guide rollers completely surrounds the pipeline. That is important in allowing the vessel to be at any angle to the path of the pipeline as may be desirable or essential when laying a pipeline in a significant current.

In a particular example of the invention, that may be employed in the case of the particular example of vessel described above, the sets of guide rollers 65A to 65F are spaced apart along the cable path at intervals of 5.2 m with the top set of rollers 65A above sea level and all the other sets below sea level. In that case the spacing between the circumferences of diametrically opposed rollers in each set is as follows:

Roller Set	Spacing (m)
65A	2.44
65B	3.54
65C	5.0
65D	6.79
65E	8.96
65F	11.48

The mountings of the sets of rollers 65A to 65C are relatively stiff and they provide the rings 77 of the sets with a radial stiffness of about 5,000kN/m with (with a maximum displacement of 100 mm), whilst the mountings of the sets of rollers 65D to 65F are less stiff and provide the rings 77 of those sets with a radial stiffness of about 1000kN/m (with a maximum displacement of 300 mm). The total load typically applied to the pipeline by all

six sets of rollers is of the order of 1000kN during normal operation, resulting in a force of about 170kN between each roller and the pipeline.

Claims:

1. A pipe-laying vessel including an upwardly extending tower assembly defining a path down which the pipe passes as a pipeline is being laid by the vessel, and a lower guide arrangement for guiding the pipeline after it has passed down the tower, the lower guide arrangement including a plurality of sets of guide rollers spaced apart along the path of the pipeline and defining the lateral limits of the path, the guide rollers being located such that they allow some bending of the pipeline as it passes through the lower guide arrangement.

2. A vessel according to claim 1, in which the guide rollers of at least one set of rollers include rollers whose axes of rotation, in a plane perpendicular to the tower, are inclined to one another.

3. A vessel according to claim 1 or 2, in which the guide rollers of at least one set of rollers extend at least one quarter of a revolution around the path of the pipeline.

4. A vessel according to claim 3, in which the guide rollers of at least one set of rollers extend substantially all around the path of the pipeline.

5. A vessel according to any preceding claim, in which the lower guide arrangement is of substantially trumpet shape flaring outwardly in the direction of travel of the pipeline during laying, and the angle of flare increasing in the direction of travel of the pipeline during laying.

6. A vessel according to any preceding claim, in which the guide rollers are freely rotatable.

7. A vessel according to any preceding claim, in which at least some of the rollers are mounted for rotation in bearings that are directly or indirectly resiliently displaceable.

8. A vessel according to claim 7, in which the resistance of the bearings to resilient displacement is more than 100kN/m.

9. A vessel according to claim 8, in which the resistance of the bearings to resilient displacement is more than 500kN/m.

10. A vessel according to any of claims 7 to 9, in which the bearings are resiliently displaceable by a distance of more than 50 mm.

11. A vessel according to claim 10, in which at least some of the bearings are resiliently displaceable by a distance of more than 100 mm.

12. A vessel according to any preceding claim, in which the inclination of the tower assembly is adjustable and the lower guide arrangement is secured to the tower assembly.

13. A vessel according to any of claims 1 to 11, in which the inclination of the tower assembly is fixed.

14. A vessel according to any preceding claim, in which the inclination of the tower assembly is in the range of 45° to 90° to the horizontal.

15. A vessel according to any preceding claim, in which three or more sets of guide rollers are positioned along the path of the pipeline below sea level.

16. A vessel according to claim 15, in which five or more sets of guide rollers are positioned along the path of the pipeline below sea level.

17. A vessel according to claim 15 or 16, in which the sets of rollers are spaced apart substantially evenly along the path of the pipeline.

18. A vessel according to any preceding claim, in which the spacing along the path of the pipeline between

adjacent sets of guide rollers is in the range of 2 m to 15 m.

19. A vessel according to any preceding claim, including means for monitoring the forces applied to the pipeline by rollers of the lower guide arrangement.

20. A vessel according to claim 19, in which a plurality of force monitoring means are associated with respective sets of guide rollers for monitoring the forces applied to the pipeline by the respective guide rollers.

21. A vessel according to any preceding claim including means for raising lengths of pipe from a deck of the vessel to a position aligned with the tower assembly and for joining such lengths of pipe to the pipeline being laid.

22. A method of laying a pipeline from a vessel, comprising lowering the pipeline down an upwardly extending tower assembly of the vessel and then through a lower guide arrangement, the lower guide arrangement including a plurality of sets of guide rollers spaced apart along the path of the pipeline and defining the lateral limits of the pipeline, the pipeline undergoing some bending as it passes through the lower guide arrangement.

23. A method according to claim 22, employing a vessel as defined in any of claims 1 to 21.

24. A method according to claim 22 or 23, in which forces exerted on the pipeline by one or more of the guide rollers are monitored and the operation of the vessel adjusted in dependence upon the monitoring.

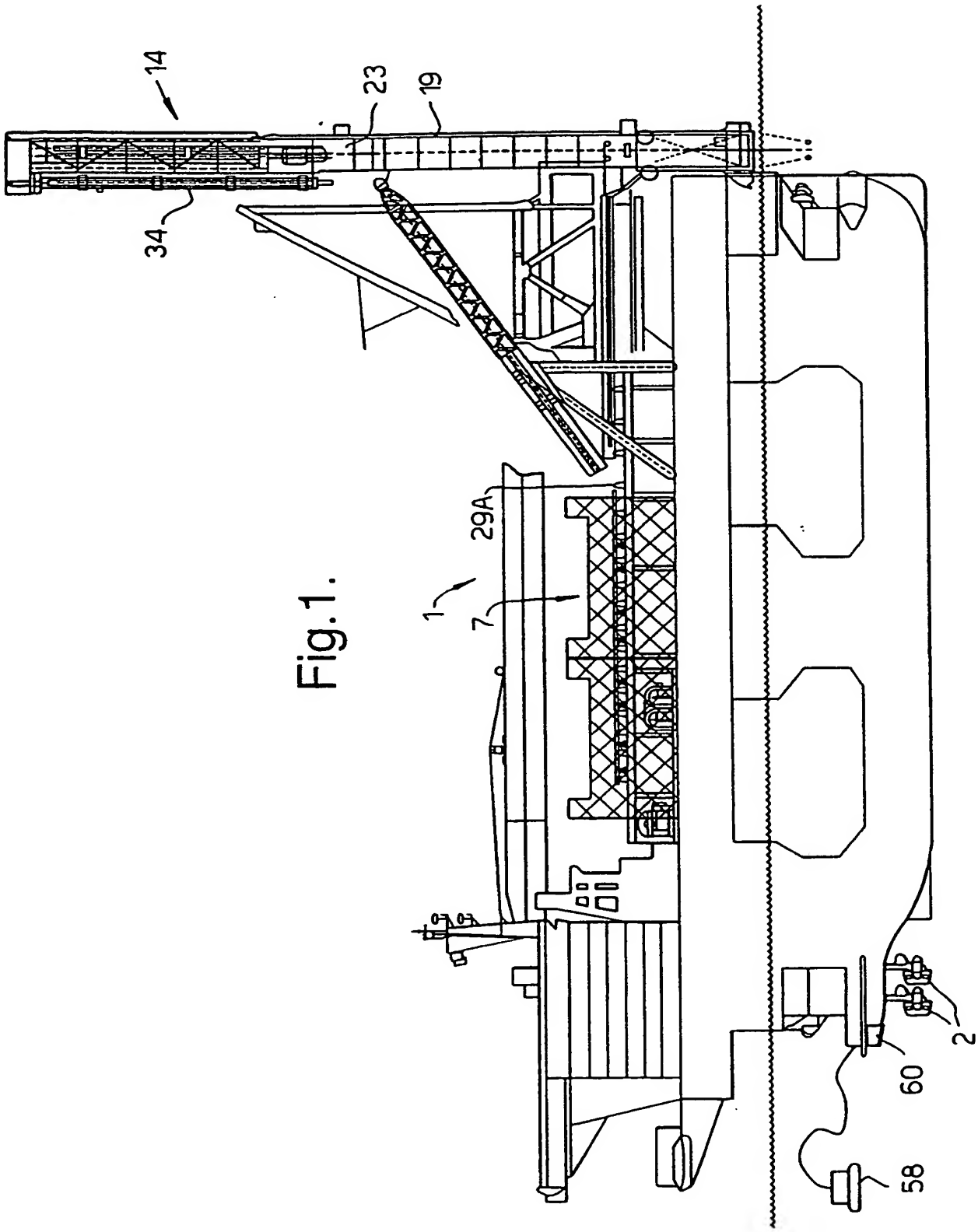
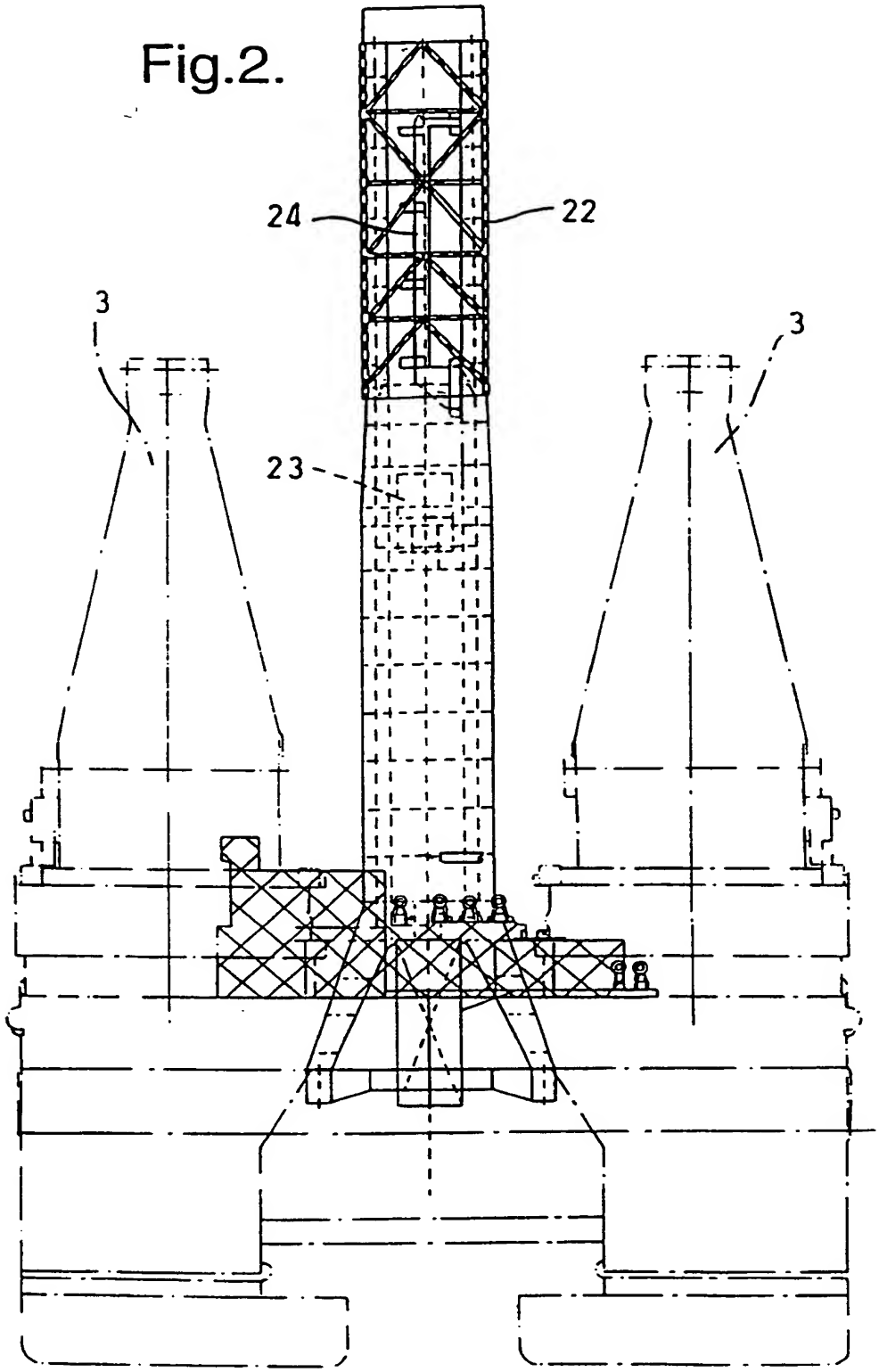


Fig.1.

Fig.2.



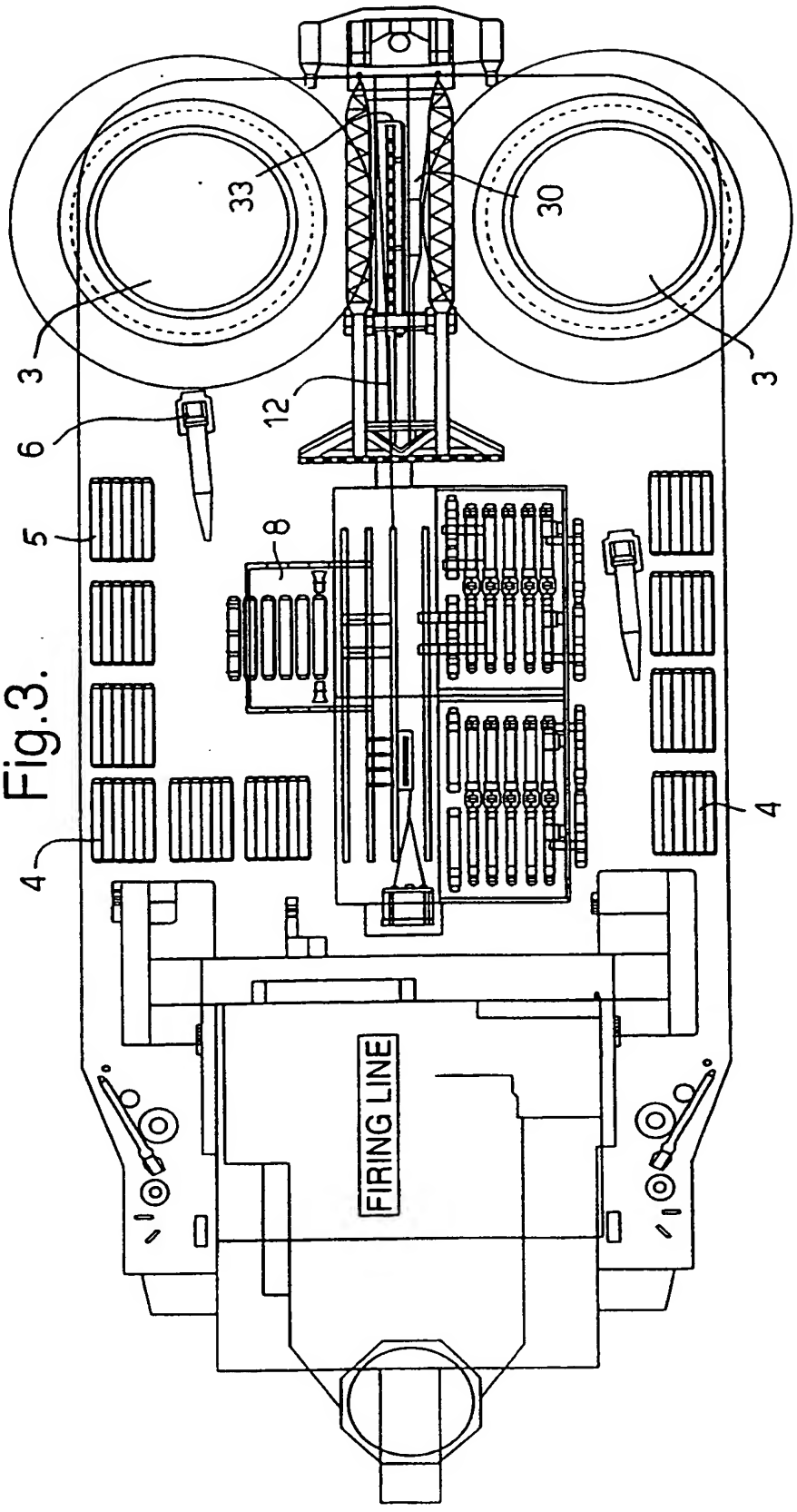


Fig.3.

Fig.4.

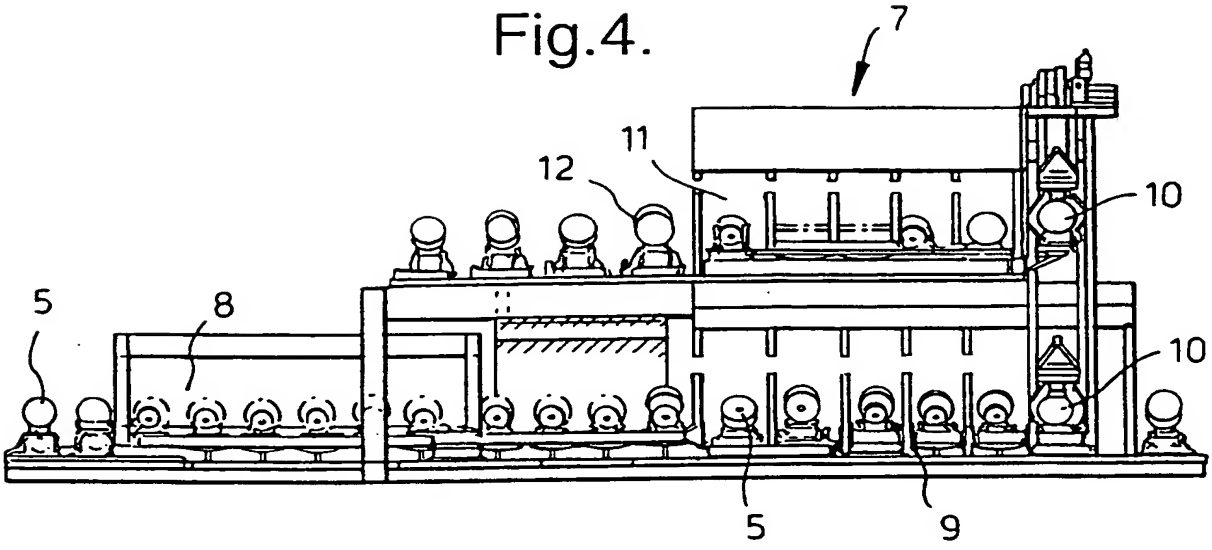
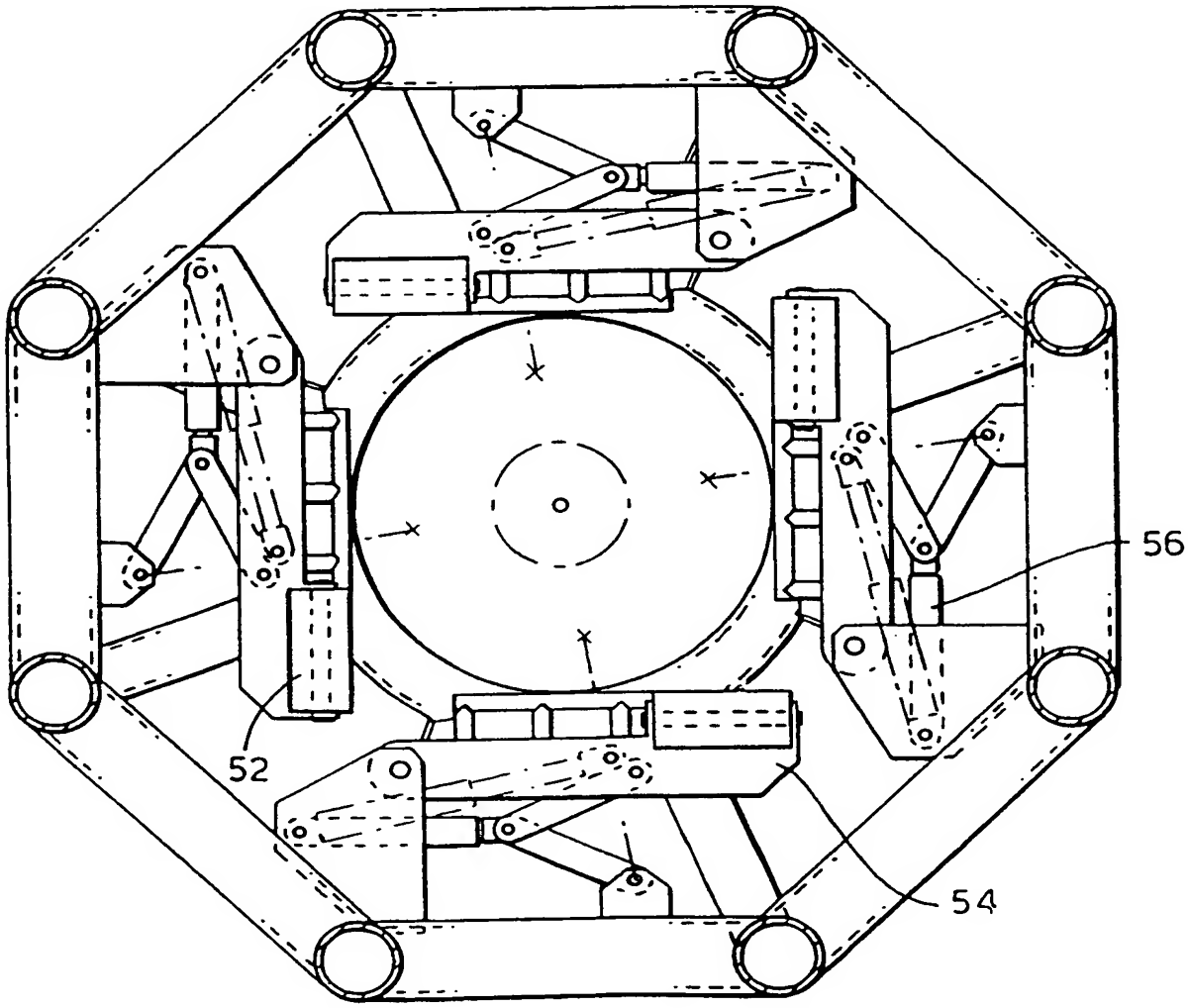


Fig.9.



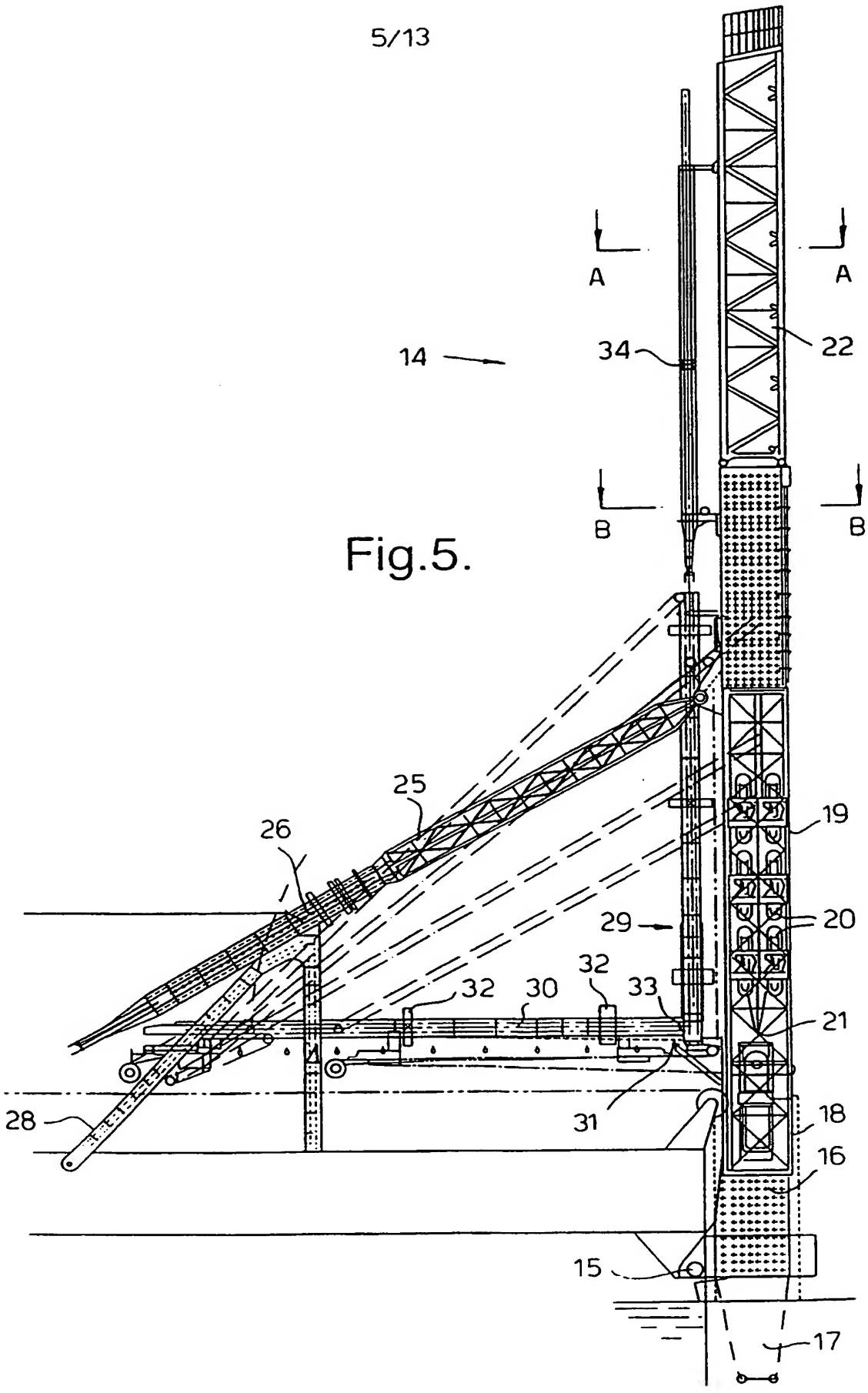


Fig.5.

Fig.6.

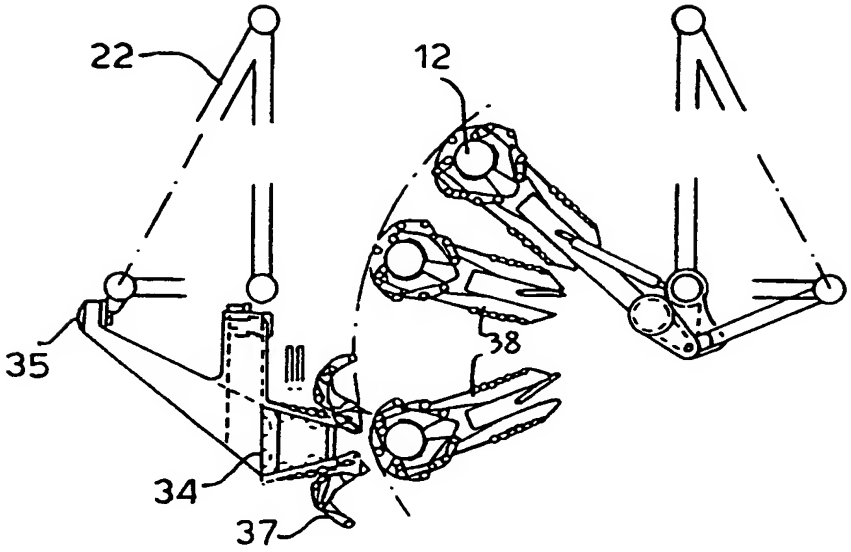
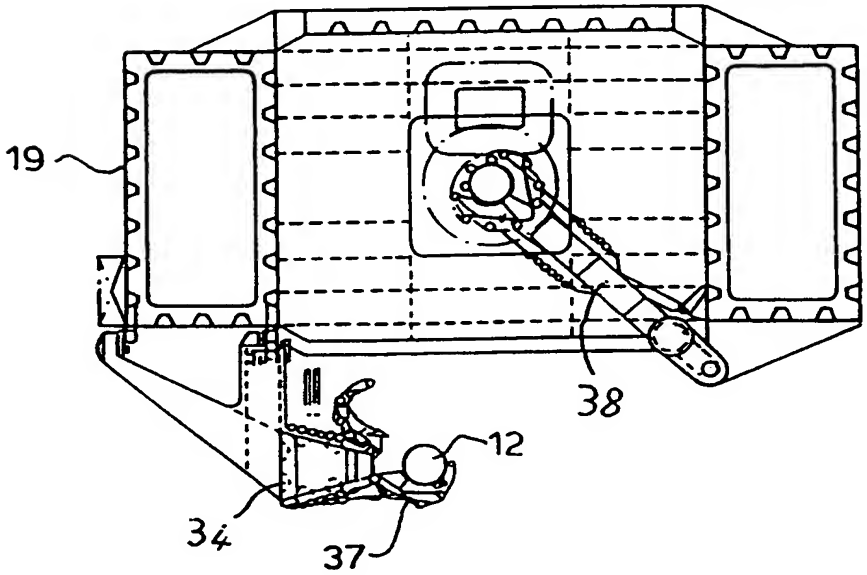


Fig.7.



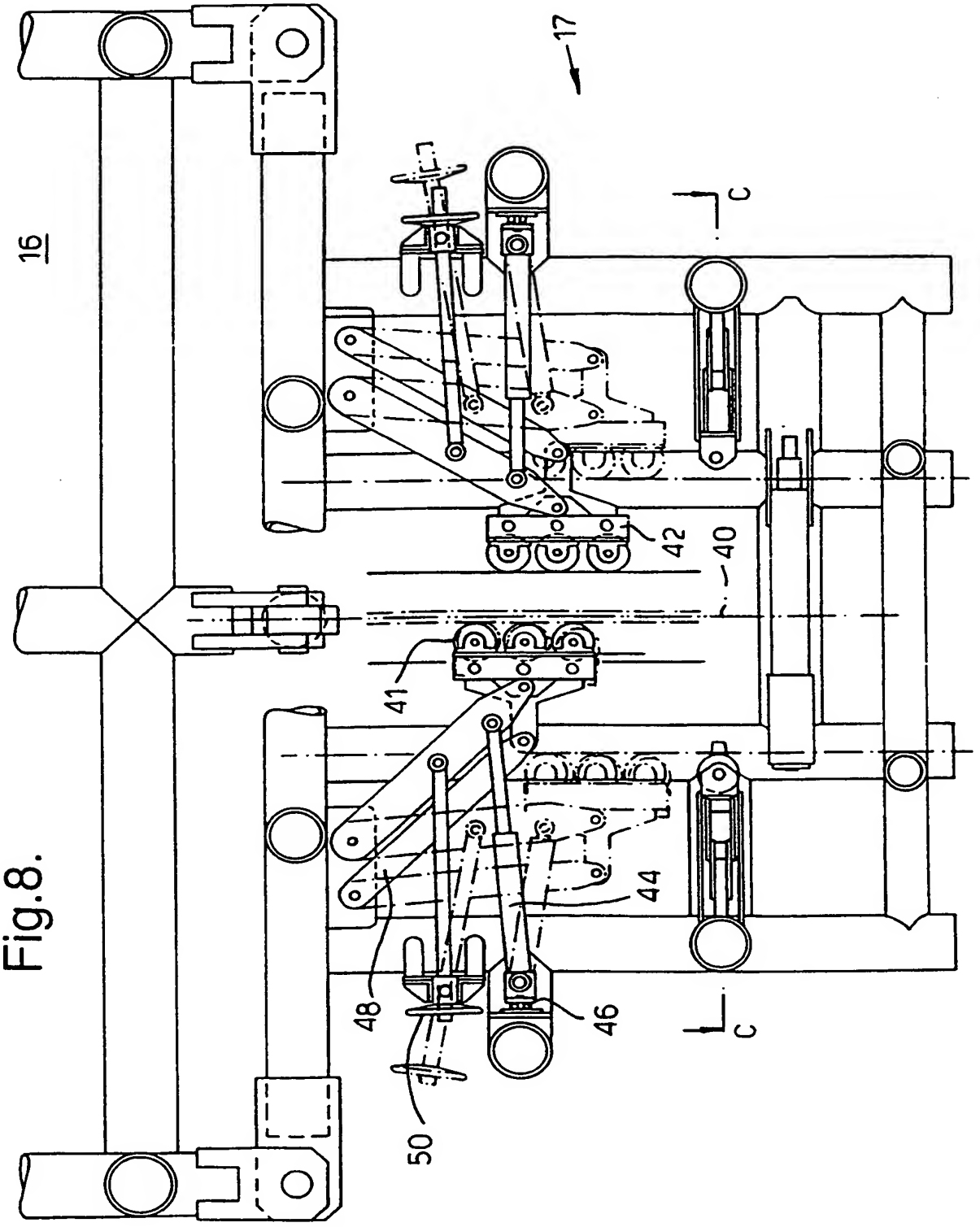


Fig.8.

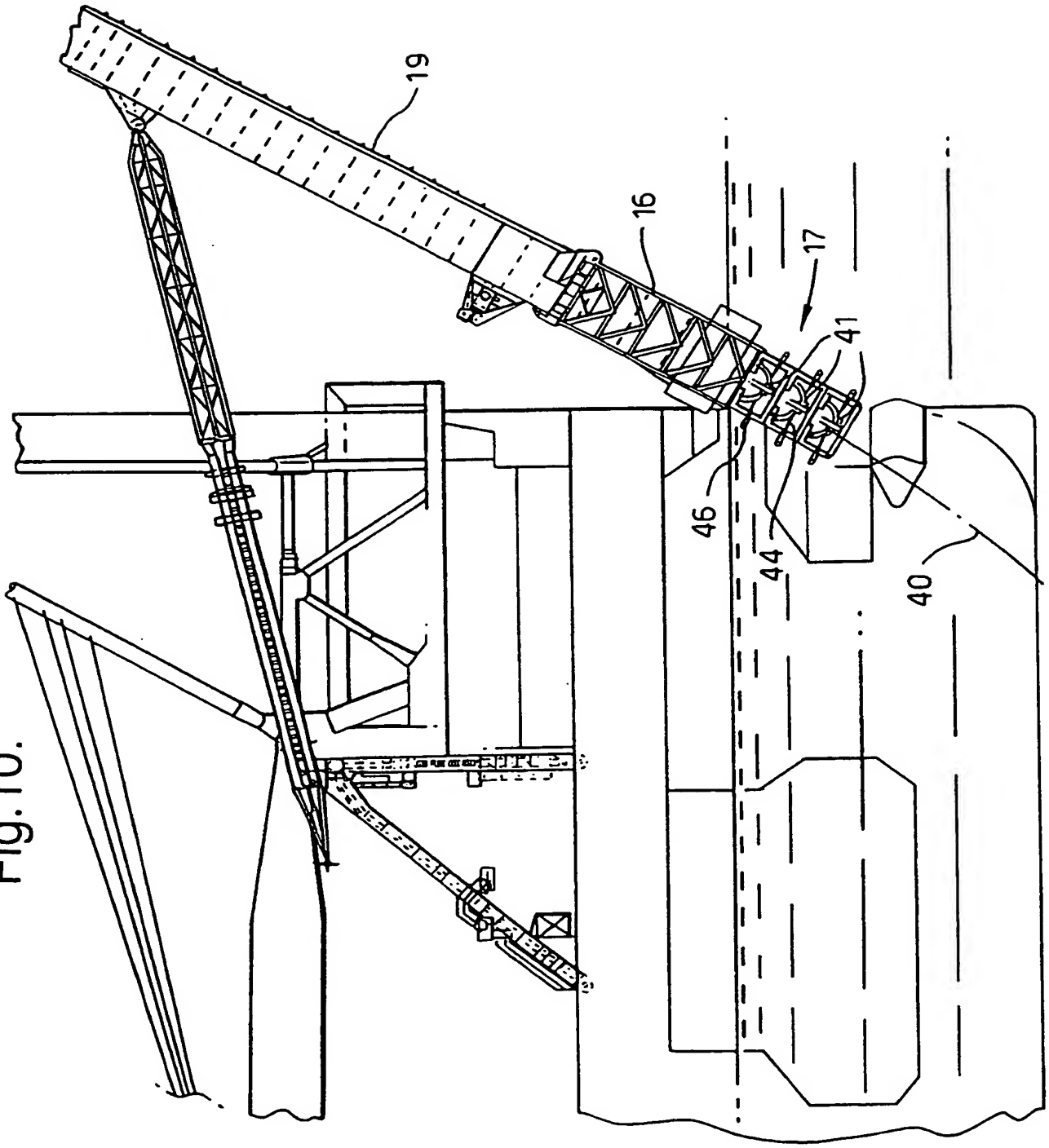


Fig.10.

Fig.11.

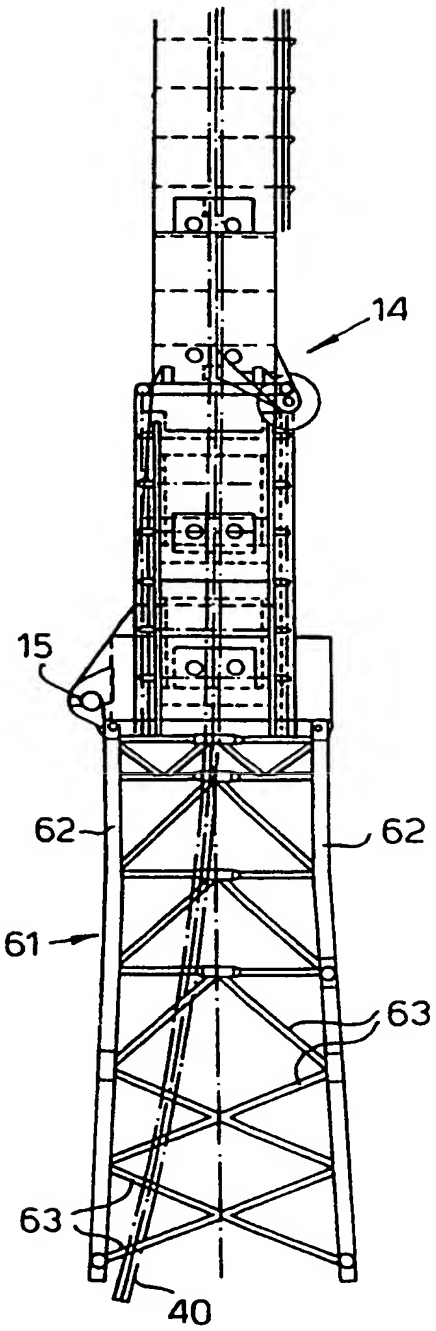


Fig.12.

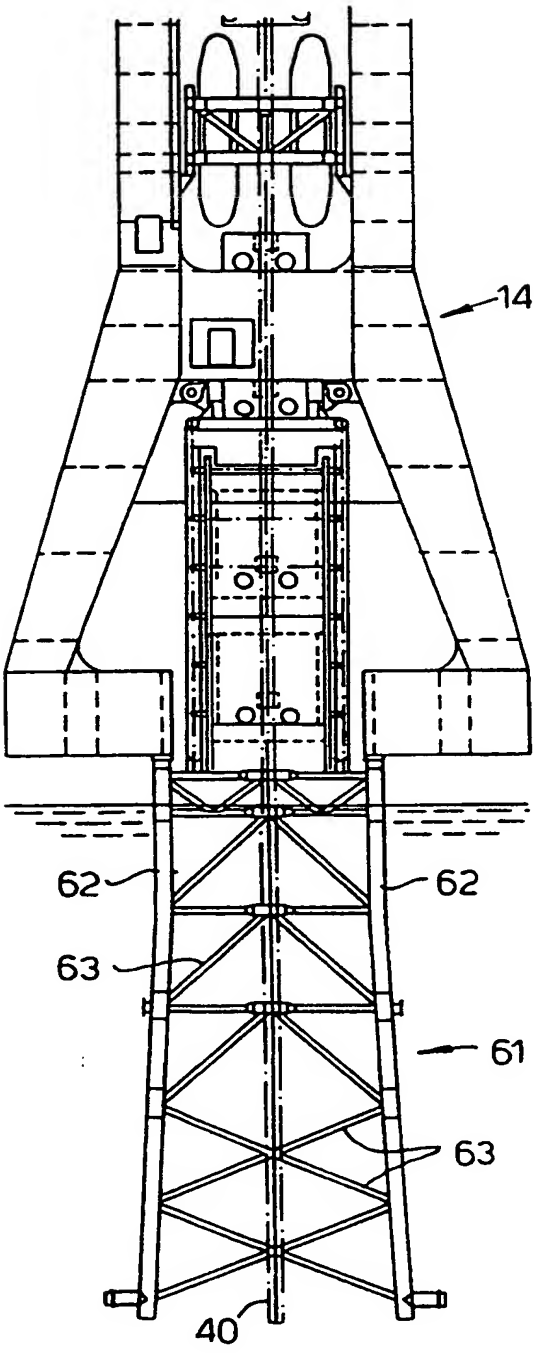


Fig.13.

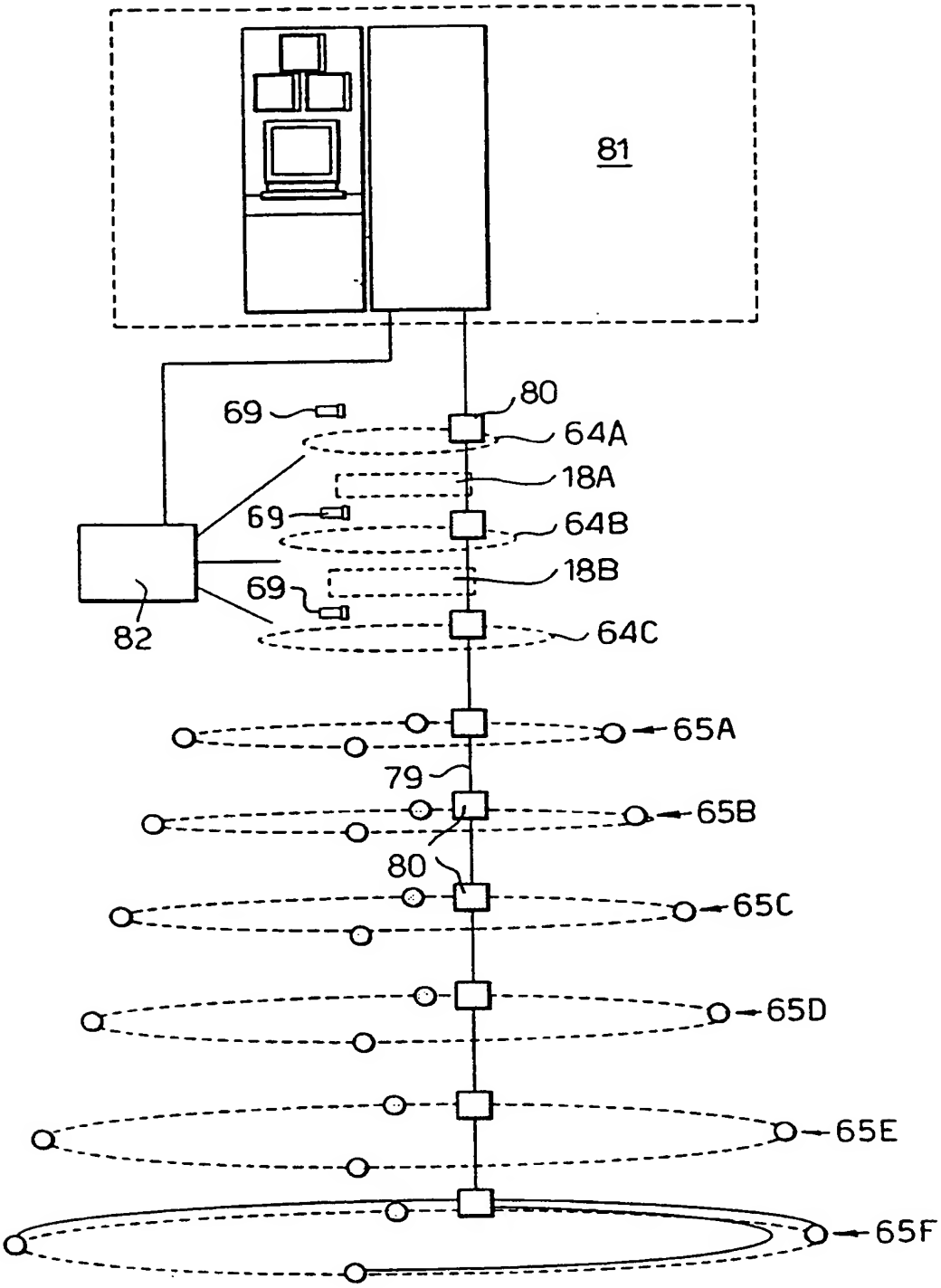


Fig.14.

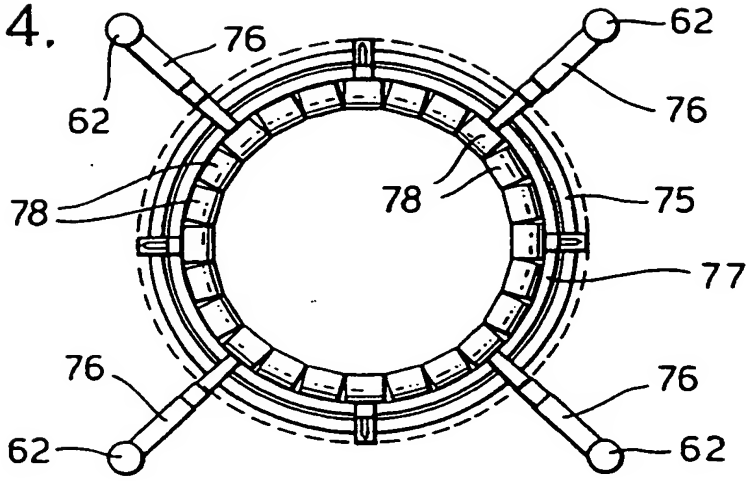


Fig.15.

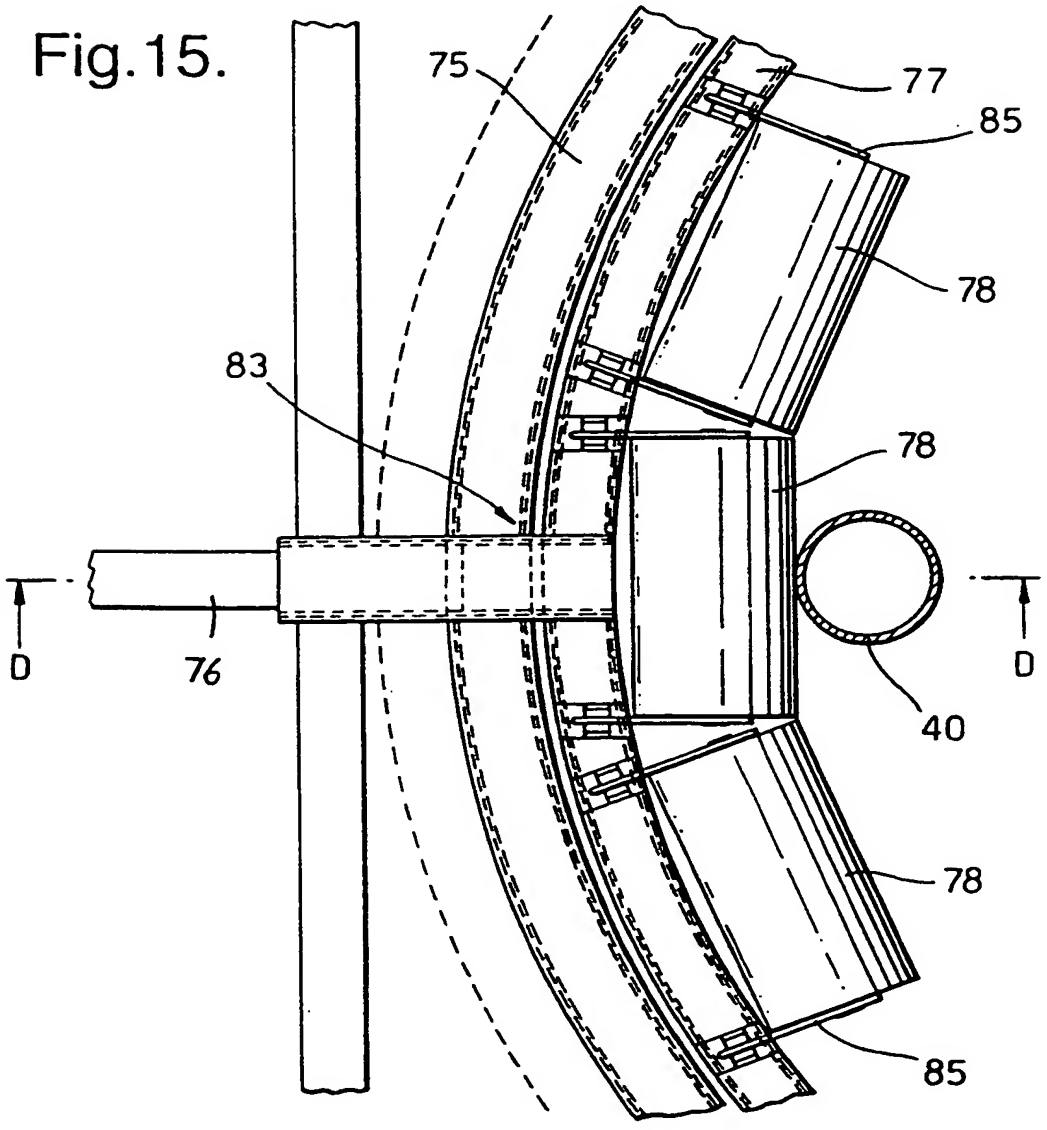


Fig.16A.

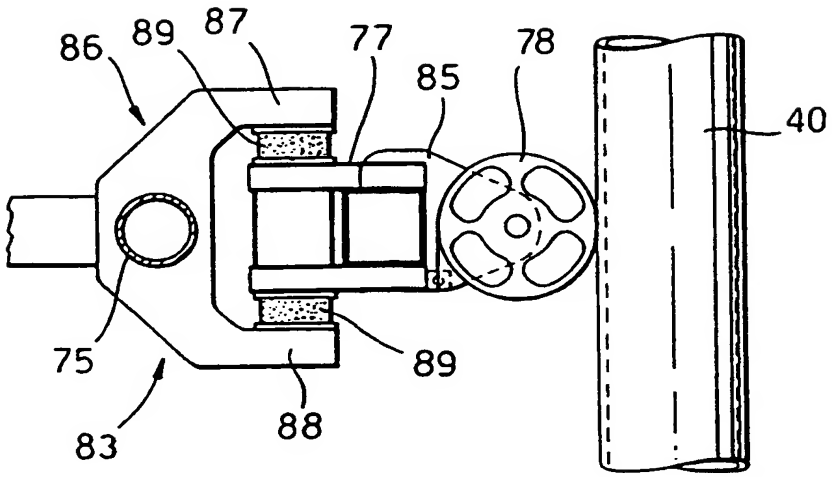


Fig.16B.

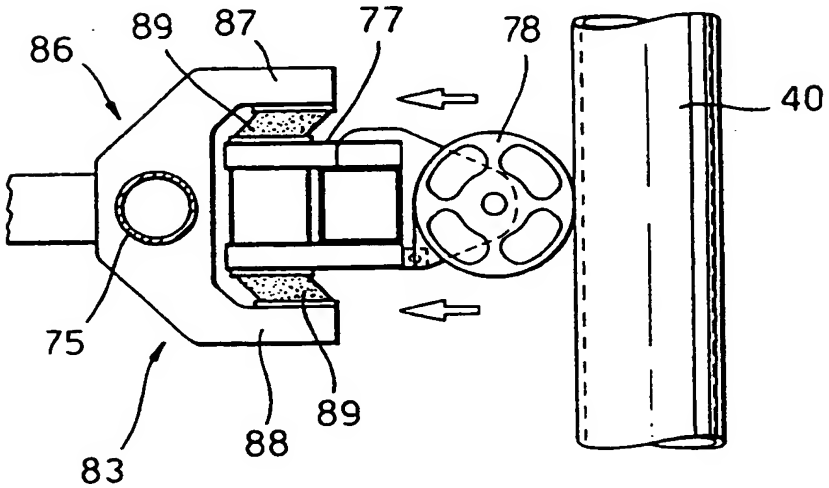


Fig.17A.

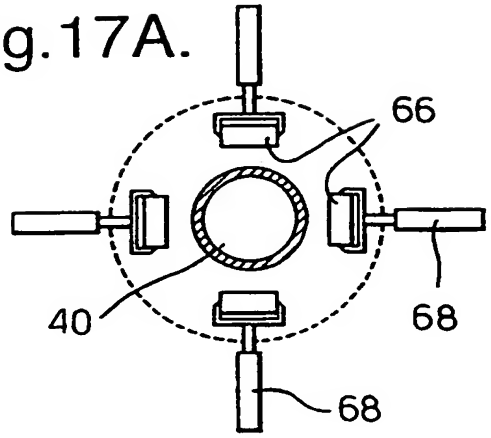


Fig.17B.

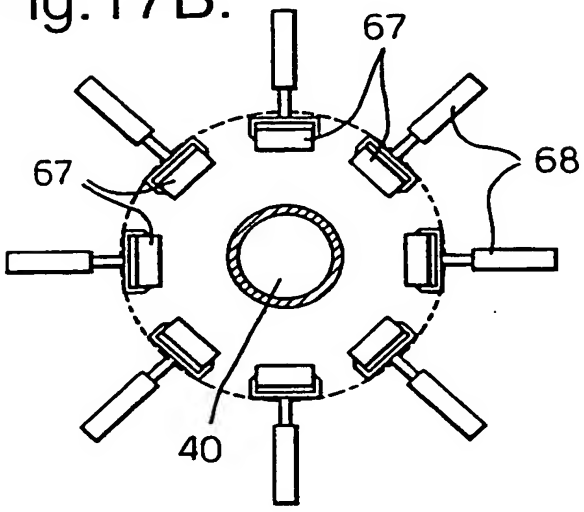
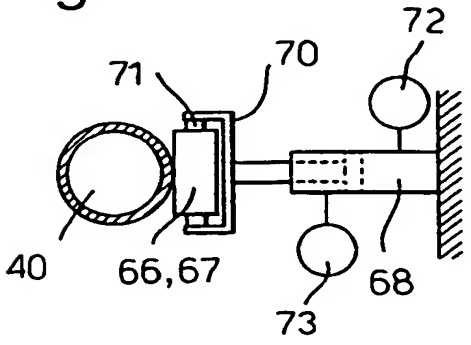


Fig.17C.



INTERNATIONAL SEARCH REPORT

Inter. ...nal Application No
PCT/EP 99/05202

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16L1/12 F16L1/19 B63B35/03

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16L B63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 21 18 360 A (BROWN & ROOT) 28 October 1971 (1971-10-28) page 6, line 4 - line 8 page 24, line 10 - line 23 figures 1,10,12A	1-4,6,7, 12, 15-17, 21-23
A		8-11,14, 18,19,24

X	US 4 865 359 A (ROBERTS RICHARD A) 12 September 1989 (1989-09-12) column 6, line 8 - line 38 figure 3	1,2, 15-17, 22,23
A		3-7,12, 18

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 March 2000	29/03/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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